THE REPORT OF THE PILOT APPLICATIONS PROJECT

DEVELOPMENT OF NEW SEASONAL CLIMATE PREDICTION TOOLS THROUGH ANALYSIS OF ONSET AND CESSATION OF SEASONAL RAINS ASSOCIATED WITH EL NINO/LA NINA EVENTS

Submitted
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NEW SEASONAL CLIMATE PREDICTION TOOLS THROUGH ANALYSIS OF ONSET AND CESSATION OF SEASONAL RAINS ASSOCIATED WITH EL NINO/LA NINA EVENTS

1. INTRODUCTION

1.1 Background

Negative impacts of climate anomalies have in the past affected vulnerability of the population in Tanzania and in many parts of the world. As a result scientists are making effort to develop climate prediction tools that will help to provide information that will enable the public and governments to take action to minimize the negative impacts of various climate scenario. Today, the value of climate information and in particular rainfall information in the planning and management of resources is enormous and demand for climate information is on the increase especially following several successive years of climate extremes (floods and droughts) in the East African sub-region.

The inter-annual and intraseasonal variability of seasonal rains in Tanzania and eastern Africa results from the complex interaction between sea surface temperature (SST) forcing, meso-scale atmospheric patterns and synoptic-scale weather disturbances. These include monsoons and trade winds especially in the adjacent oceans, sub-tropical anti-cyclones, and tropical cyclones, easterly/westerly wave perturbations and extra-tropical weather systems. The extent to which SSTs influence the seasonal rainfall totals in Tanzania and the sub-region has been widely studied. Its contribution to both unimodal and bimodal regions showed significant stronger relationships. Hence the seasonal forecasts in the region, especially for the October to December (OND) and December to February (DJF) seasons are based to a greater extent on global ocean Sea Surface Temperature Anomalies and the Southern Oscillation Index (SOI).

Rainfall over the eastern and southern Africa region has demonstrated dipole patterns such that when the equatorial eastern Africa region is dry then the southern Africa region is wet and vice versa. But this dipole pattern in rainfall does not occur always. There are some years this dipole pattern does not hold. For instance similar rainfall anomalies existed for Southern and Eastern Africa during the 1997 El Nino event and 1999 La - Nina episodes. Dipole behavior has also been observed in the SST patterns over the Indian Ocean showing gradients in the SST between central Indian Ocean and Indonesia suggesting mutual influence between Pacific and Indian Oceans. This influence results in cyclic warming and cooling of the surface ocean commonly referred to as El Nino Southern Oscillation (ENSO). Extreme rainfall anomalies in East Africa have statistically been associated with ENSO. Although the predicting skill is of modest level over places like Lake Victoria basin, parts of coastal areas and north eastern highlands of Tanzania, studies have shown a likelihood of wet or dry conditions in the region during ENSO or La Nina years respectively. Significant teleconnections between Eastern African seasonal rainfalls and ENSO have been documented. The good skills of predicting ENSO phases up to a year in advance suggests good prospects of monitoring and successful applications of ENSO forecasts to seasonal climate prediction in East Africa especially the October to December rainy periods. It has also been noted that there is a relationship between ENSO occurrence over the central Pacific and the SST anomalies over the Atlantic Ocean. During El Niño episodes, the Walker circulation weakens and the SOI becomes negative. Typical examples of large negative SOI values derived out of the 6-month (April to September) average are the 1982 drought of which SOI was –16 and the 1997/98 flood rains when it was -17.8.

1.2 Climate of Tanzania

The climate of Tanzania exhibits two distinct rainfall seasonal patterns, namely bimodal and unimodal rainfall regimes. Bimodal behavior exists over northern Tanzania and unimodal over western, central and southern Tanzania. The bimodal rainfall is characterized by two annual maxima i.e. the long rains in March–May and the short rainfall season between October–December. Further studies have split the bimodal and unimodal regimes into several homogeneous zones. The homogeneous zones over the bimodal areas include northern coast, Zanzibar isles, north eastern highlands and Lake Victoria basin. For the unimodal areas they are western, central, southwestern highlands and southern areas.

According to Hastenrath et al (1993), the interannual variability of rainfall in the March–May rainfall has characteristics different to that in October–December. The former being much less persistent within the season and being associated with intraseasonally changing large-scale patterns of surface temperature, sea level pressure and winds. Zorita and Tilya (2002) have also shown that March and April rainfall anomalies are linked to zonal thermal contrast between the Indian Ocean and the Eastern African land mass, to zonal surface wind anomalies and to vertical velocity anomalies while May rainfall anomalies are associated with a meridional surface temperature contrast between the Indian Ocean and the Asian continent and meridional surface wind anomalies. The short rains experienced between October and December unlike the long rains has been shown by Nicholson and Entekhabi (1987); Ogallo (1989); Nyenzi et al (1992); Mutai et al (1998); to be greatly influenced by tropical sea surface temperature in Indian as well as Pacific Oceans and responds effectively to the SOI.
El Niño events shows increased rainfall across majority of the bimodal parts of coastal areas north of Mafia Island and hinterland (NCH), North Eastern Highlands (NEH), Lake Victoria basin (LVB) featuring mainly during the short rains and over most parts of the unimodal areas of which the season sets in late October with a peak in January. However, the precise nature of the impact differs

quite markedly from one event to another, even with similar changes and patterns in the Pacific Ocean and Indian Ocean. Timely rains that made a significant difference to the season punctuated the progress of some events. For example, the 1982/83 and 1997/98 events were both very strong as measured by changes in the Pacific, yet their impacts in the season lengths were completely different. The seasons were shorter in 1982/83 yet useful as they yielded very useful harvests as compared to 1997/98 season, which was longer but plunged the country in crisis as a result of widespread floods due to abnormally heavy rains.
The unimodal areas of Tanzania get most of the rainfall during November to March a time when the North East monsoon sweeps across the west Indian ocean thus delivering moisture coupled with shifting of the convective activities over the Congo basin across these areas towards south west Indian Ocean as shown by Jury and Mpeta (2002) in response to the sea surface temperature changes in tropical Indian and Pacific Oceans.

1.3 Objective

Southern Oscillation Index (SOI) is among known indicators that qualitatively signal evolution of sea surface temperature in tropical Pacific leading to recognition of El Nino and La Nina years by giving a simple measure of the strength and phase of the Southern Oscillation and the status of the Walker circulation. It is with this knowledge that this study is being carried out to asses the behaviour of seasonal rainfall and amounts during normal years and during the El Niño and La Nina years.

Advances in climate modeling and prediction have made a significant step in the prediction of occurrence of El-Nina/La Nina episodes in the Pacific Ocean and their teleconnection with weather in several regions of the world. Recent studies have revealed that rainfall much of Tanzania is affected by the influenced by the El-Nino/La-Nina events particularly during the October-December rainfall season.

Recent research studies have revealed that there is good relationship between El Nino and La Nina phenomena with rainfall variability in the country. ENSO may account for about 50 to 60 percent of rainfall variability in Tanzania. It is therefore important to maximize the use of current knowledge on the relationships between the two.
Seasonal outlooks have improved in accuracy during the last several years onset and cessation of the seasonal rains, particularly during El-Nino/La Nina which have revealed strong association with rainfall variability in Tanzania. It is also important to know about the probabilities of occurrence of dry spells during the rainy season and their teleconnection with ENSO events. The output of such a study will add value to seasonal forecasts, which are already appreciated by multipurpose user community. The overall objective of the study is to add value to the climate forecasts by identifying the trends of onset, cessation dates and variability within a season particularly during El-Nino/La Nina years.

This information is important to various users particularly for agricultural planning and production. Advance knowledge of the onset will help farmers determine correct planting dates rather than waiting for it to rain before planting. Similarly, advance information on cessation will also help farmers to know the expected length of the season and hence be able to determine type and variety of crops to be planted based on the expected season.

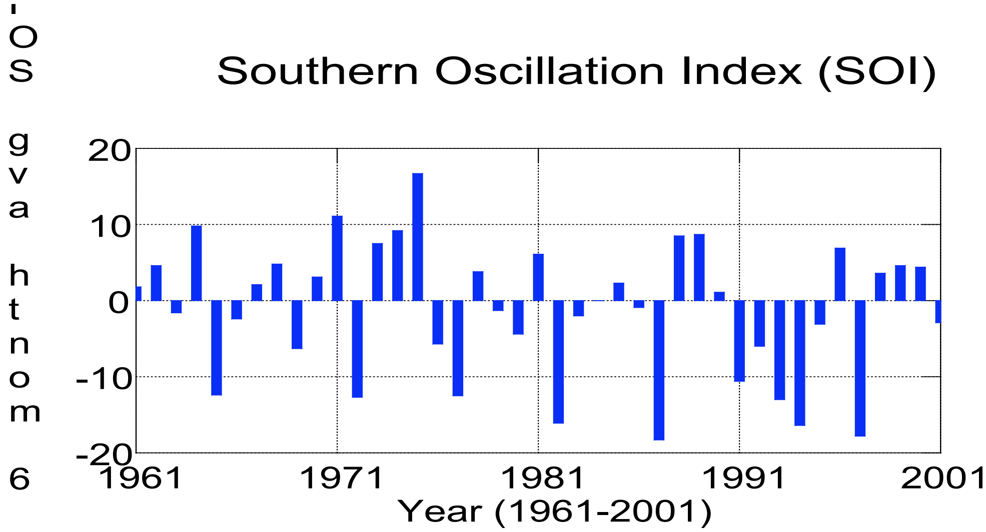

Figure 1: Large negative values indicate El Nino events while large positive indicates La Nina episodes.

2 DATA AND METHODOLOGY

2.1 Data

Rainfall and temperature data from 67 stations in the country were used in this analysis. The stations were grouped into 10 homogeneous zones of Tanzania developed using rainfall data using Principal Component Analysis as shown by Ogallo (1986) and Mutoni 2001. The rainfall and temperature data for the period 1961 to 2001 were obtained from the Tanzania Meteorological Agency. Average April-September SOI data for the same period obtained by the courtesy of Bureau of Meteorology, Australia was also used along as predictor field. The El Nino years used are of 1963, 1965/66, 1969, 1972/73, 1976/77, 1982/83, 1986/87, 1991-95 and 1997/98 while the La Nina years were those of 1964, 1971/72, 1974/75, 1976/77, 1988/89 and 1998-2000. The network of stations and derived homogeneous zones are shown in figure 2.

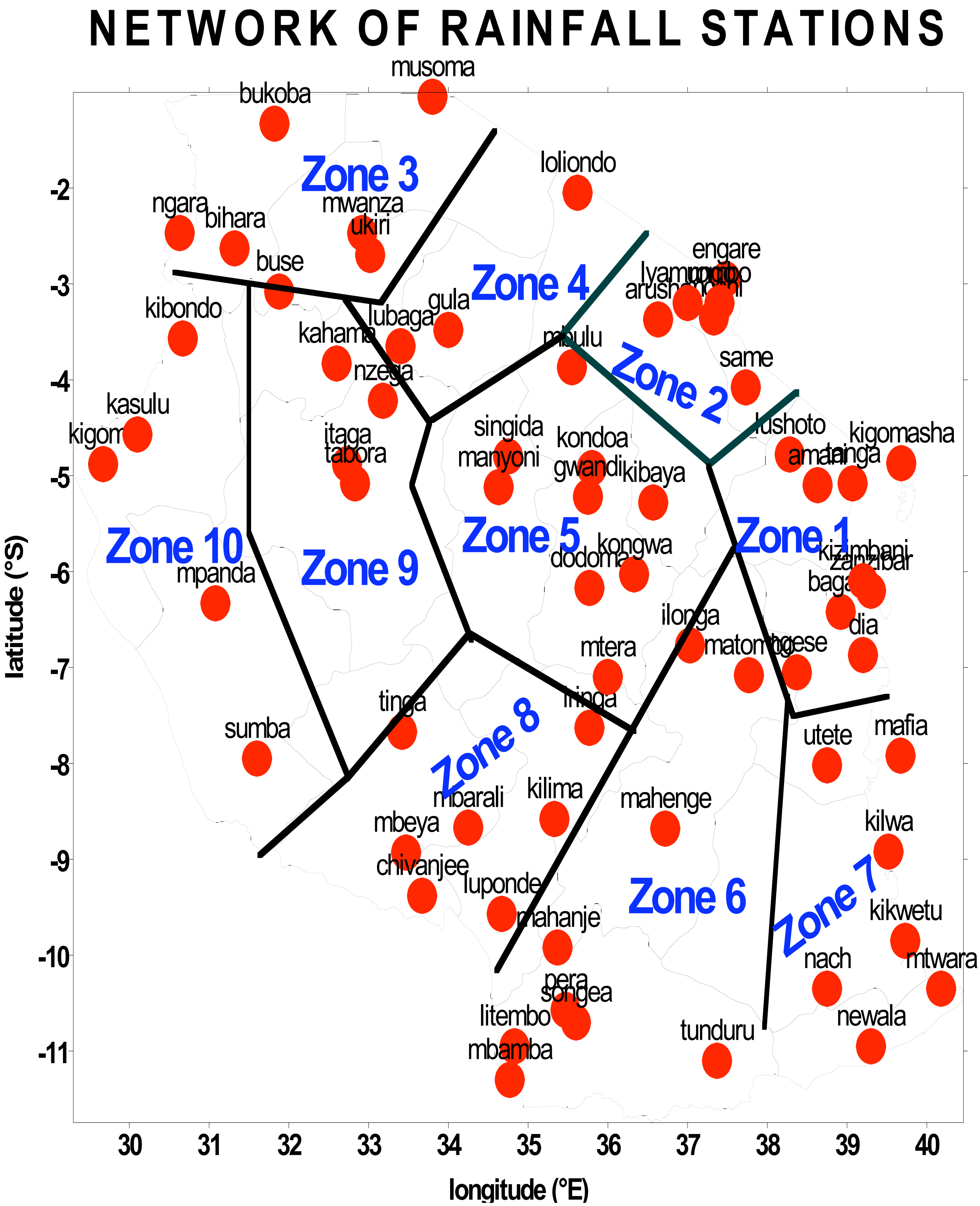

Figure 2: Network of data stations (mainly rainfall) as grouped in homogeneous zones of Tanzania.

2.2 Seasonal rainfall analysis over the bimodal areas

Statistical analysis was used to establish how rainfall patterns at locations and homogeneous areas in the country relate to the cyclic anomalous warming and cooling in the tropical Pacific Ocean.

Comparison of the rainfall amounts during MAM and OND seasons was made in order to establish the relative intensity at the times of El Nino/La Nina years. This exercise holds only for the bimodal regime identified to have two distinct seasons. It was done for each year for all stations in the bimodal regime. Standardized anomalies were computed and the two seasons were compared graphically in the three homogeneous zones namely zone1, zone2 and zone 3 of the bimodal regime to assess the performance of the two seasons for the entire record length of 41 years over point rainfall and spatially through areal average rainfall as shown in figures 3 (a), (b) and (c).

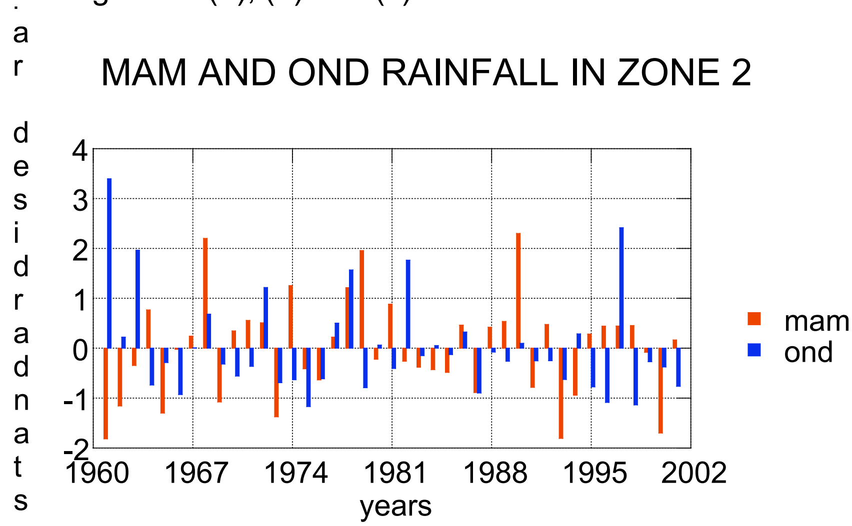

Figure 3 (a): OND > MAM 16 times in years 1961, 1962, 1963, 1965, 1969, 1972, 1977, 1978, 1982, 1984, 1985, 1991, 1993, 1994, 1997 and 2000.

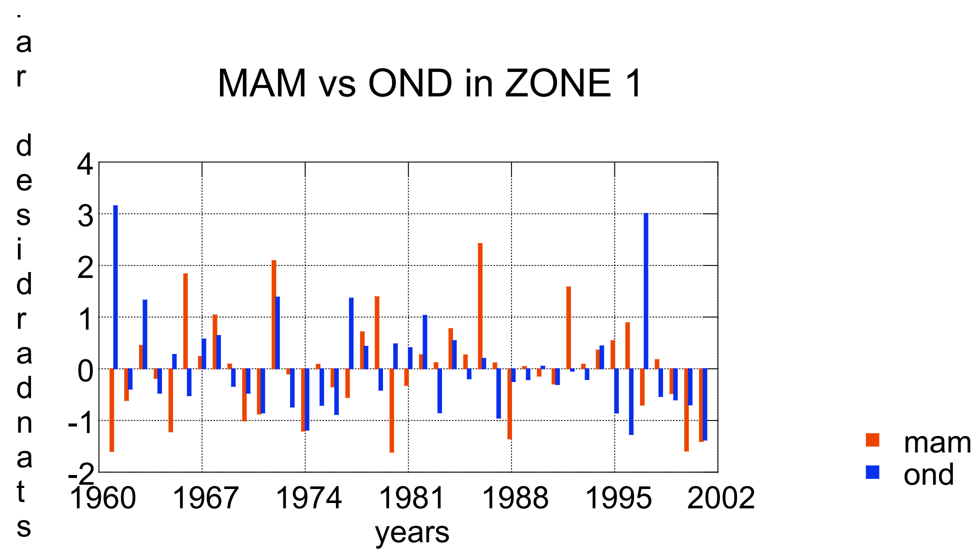

Figure 3 (b): OND > MAM 13 times in years 1961, 1962, 1963, 1965, 1967, 1970, 1977, 1980, 1981, 1982, 1988, 1997 and 2000.

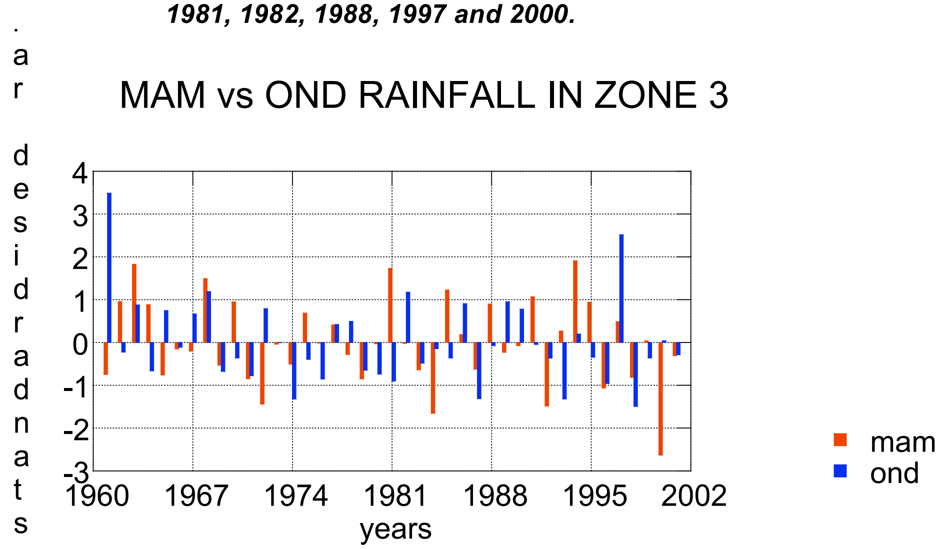

Figure 3 (c): OND > MAM 16 times in years 1961, 1965, 1967, 1972, 1978, 1979, 1982, 1983, 1984, 1986, 1989, 1990, 1992, 1996, 1997 and 2000.

It is seen from figure 3 (a), (b) and (c) above that OND had more rain than MAM for 13 to 16 years out of the 41 years of study. As shown in above figures, standardized rainfall anomalies marked by blue bars representing OND show many positive values than their red bars for MAM. Indications show that this is experienced over the bimodal regime coinciding with the El Nino years of 1963, 1965/66, 1969, 1972/73, 1976/77, 1982/83, 1986/87, 1991-95 and 1997/98 (see document Coronet Books by Ross Couper – Johnston). It was also noted that all point rainfall stations in the three zones and their corresponding areal average rainfall in 1961, which was heavier than that in 1997/98, although this particular year was not an l El Nino year. On the other hand, the most significant La Nina events occurred in 1964, 1971/72, 1974/75, 1976/77, 1988/89 and 1998-2000 the time of which the three zones experienced the most OND seasonal rainfall deficits.

2.3 Characteristics of rainfall in normal years compared to EL Nino/La Nina years

A study was done to analyse the annual characteristics of the seasonal rainfall between September and August in the subsequent year with the intention of comparing rainfall in normal years with those during El Nino and La Nina years mentioned in 2.1 above. Emphasis was specifically put on rainfall experienced in between November and February (unimodal areas) and October to December (bimodal areas), the best time when the El Nino and La Nina events reach their maximum strengths, thereby creating a platform for improved understanding in the behavior of seasonal rainfall at times of onset, cessation and lengths of rainfall seasons during El Nino, La Nina and normal years. In the analysis 10-day total rainfall data as well as 10-day mean temperatures were used to identify the distribution. Computation of areal average for the zones was carried out to point stations to minimize variations that may arise due to local effects. The temperature network in the country is rather sparse compared to rainfall as such a single station may feature for a zone like in zone 7. However, its contribution is considered uniquely important from the fact that its variation is always much smaller and happens gradually with time unlike rainfall. Graphical results are presented below.

2.3.1 Zone 7

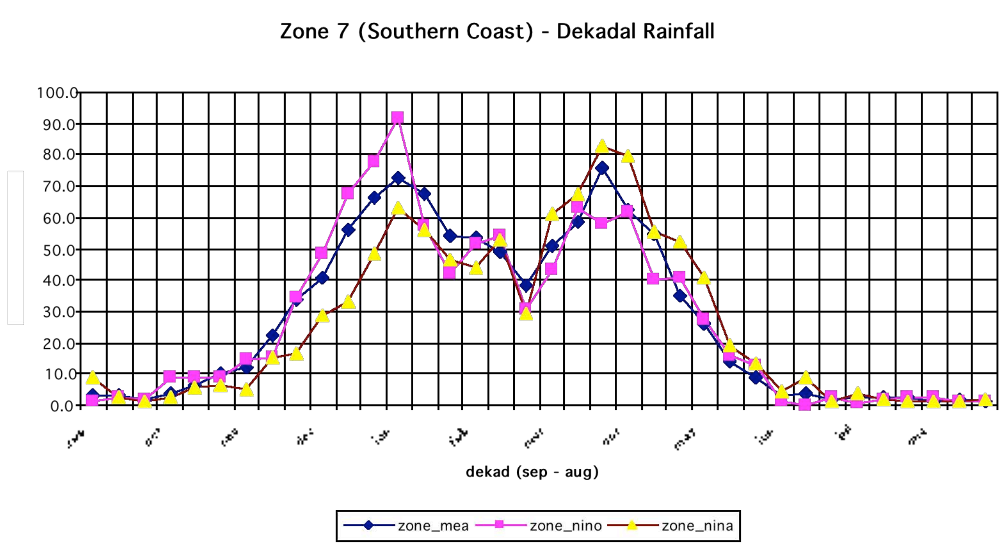

Figure 4 (a): areal average rainfall based on 7rainfall stations.

2.3.2 Zone 1

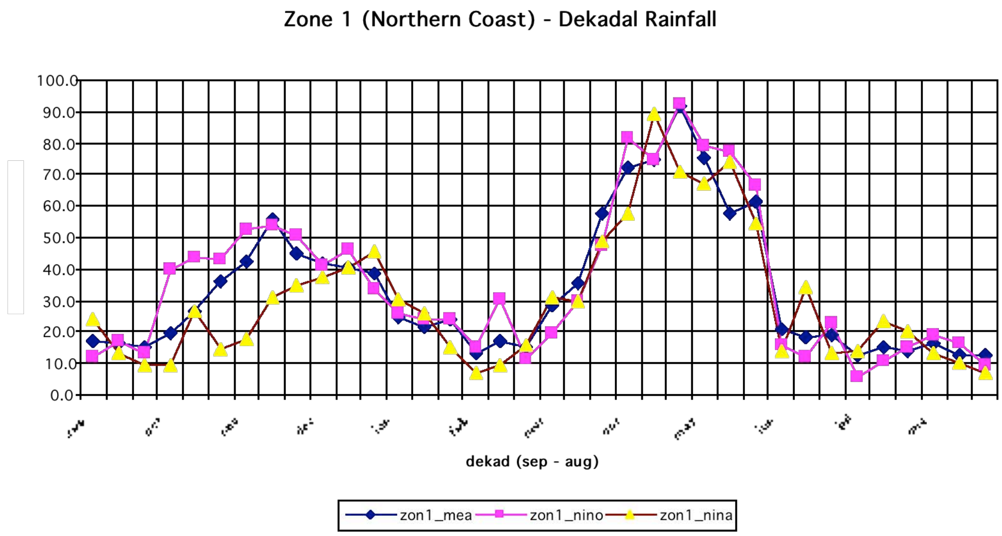

Figure 5 (a): areal average rainfall based on 9 rainfall stations.

2.3.3 Zone 2

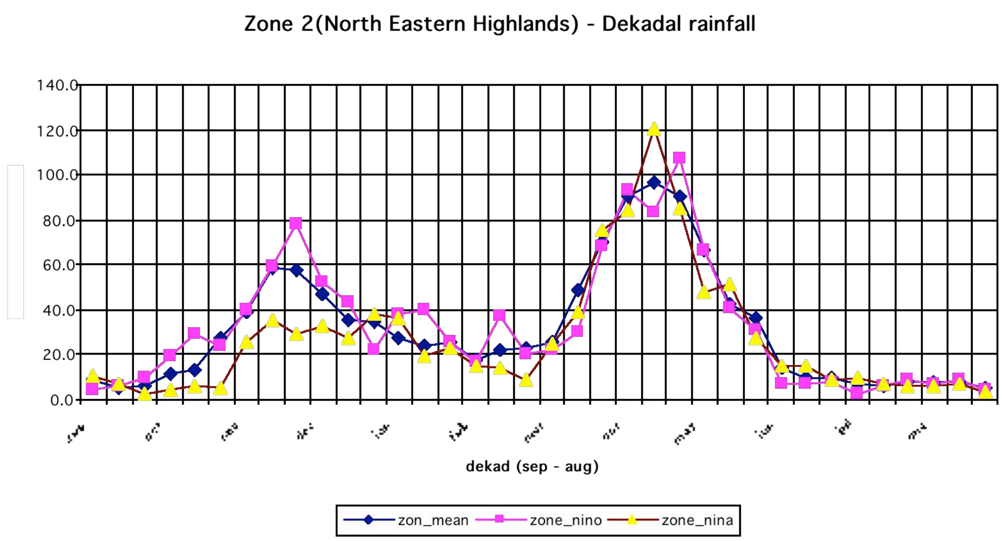

Figure 6 (a): areal average rainfall based on 6 rainfall stations

2.3.4 Zone 3

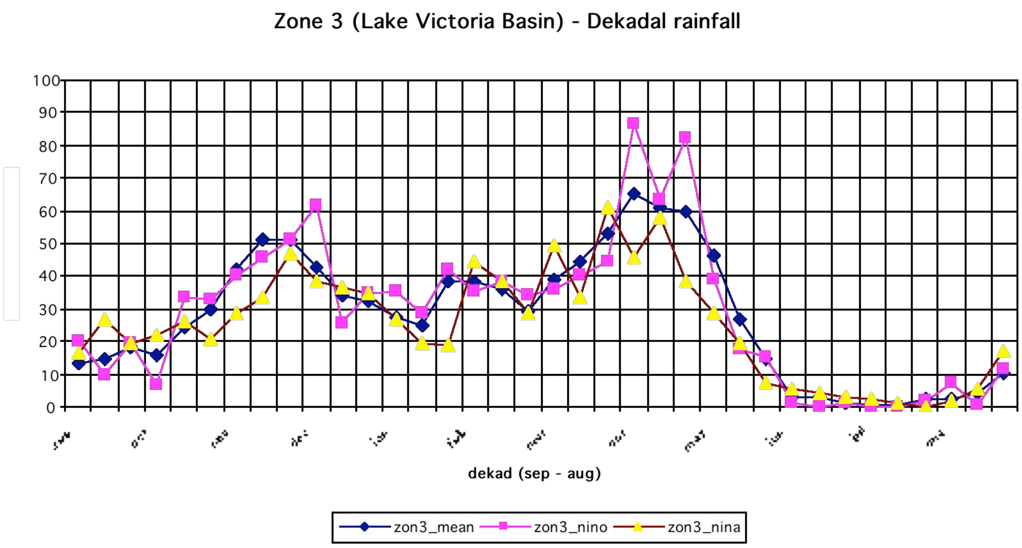

Figure 7 (a): areal average rainfall based on 6 rainfall stations

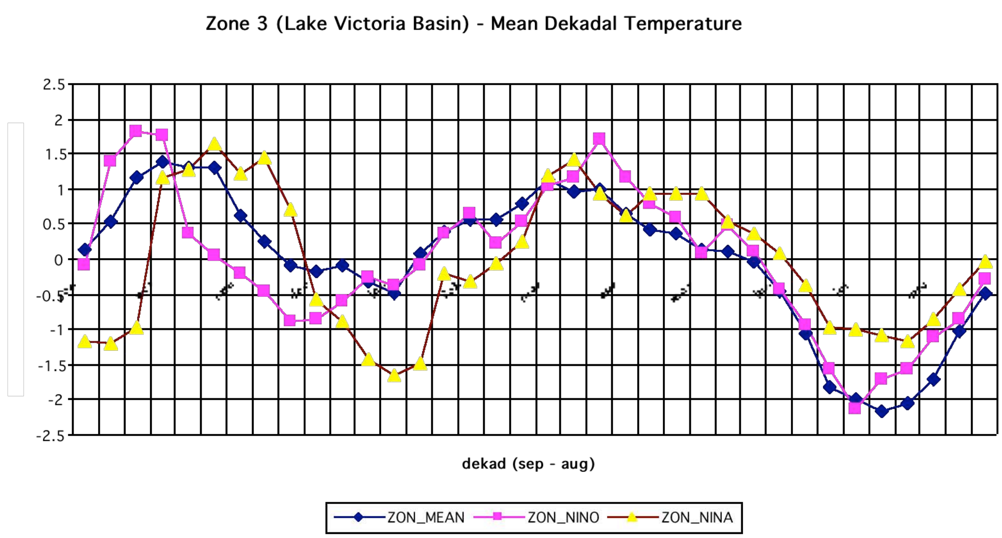

Figure 7 (b): areal average temperature based on 3 rainfall stations

2.3.5 Zone 4

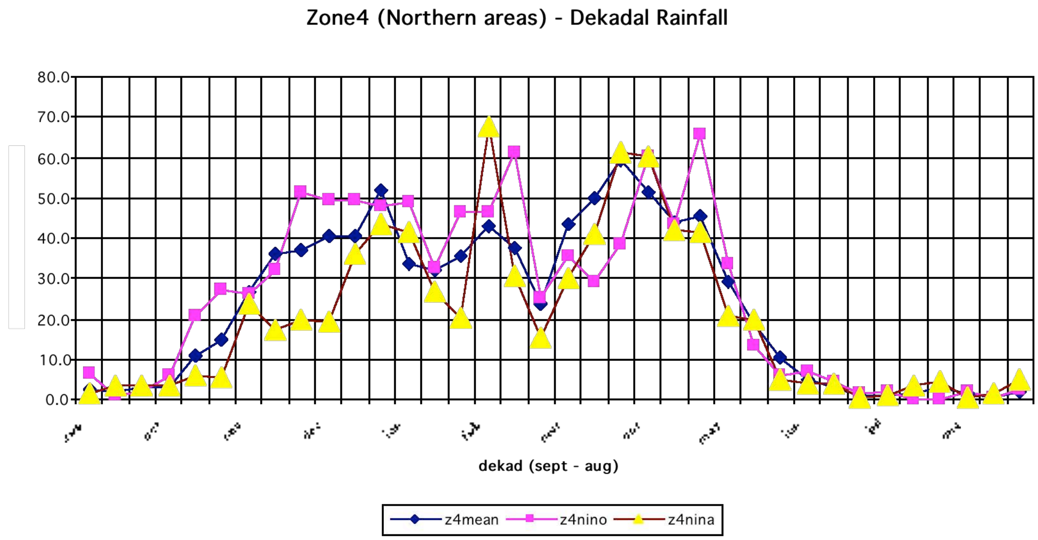

Figure8: areal average rainfall based on 3 rainfall stations

2.3.6 Zone 5 – Central areas

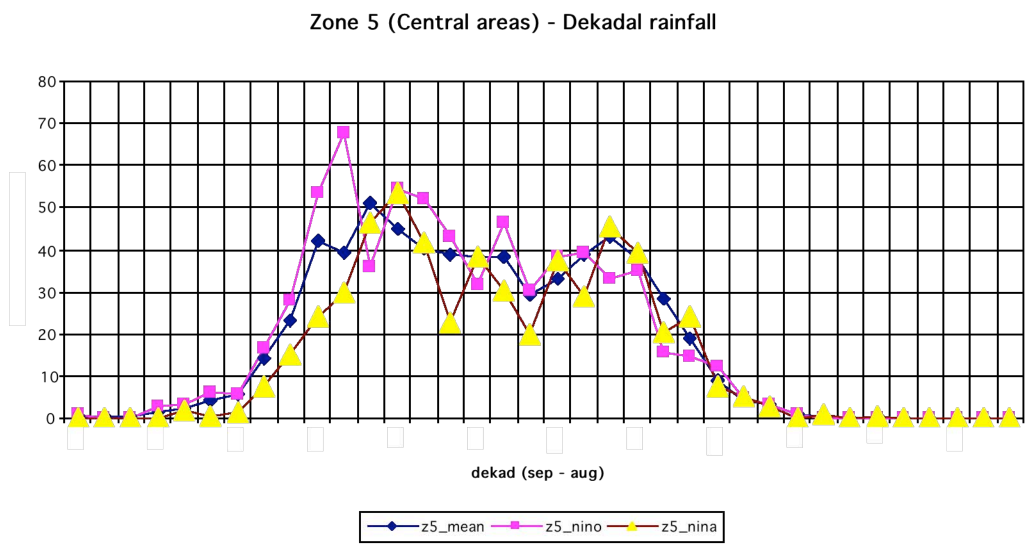

Figure9: (a) areal average rainfall based on 8 rainfall stations

Zone 5 (Central areas) - Mean dekadal Temperature

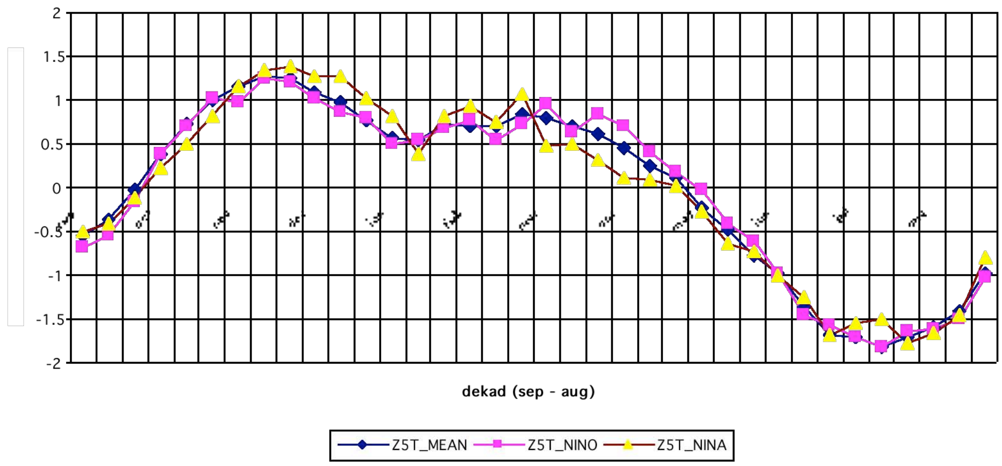

Figure9: (b) areal average temperature based on 2stations

2.3.7 Zone 6 – Southern areas

Zone6 (Southern areas) - Dekadal rainfall

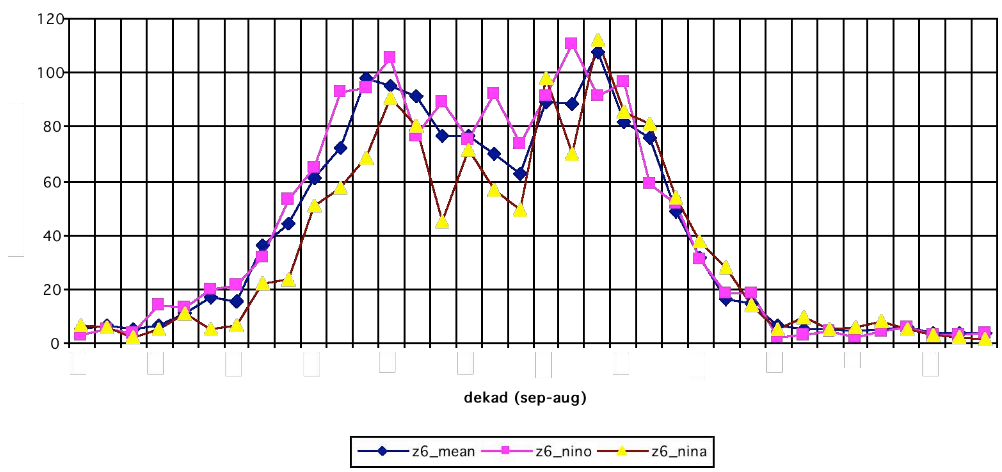

Figure 10: (a) areal average rainfall based on 8 stations

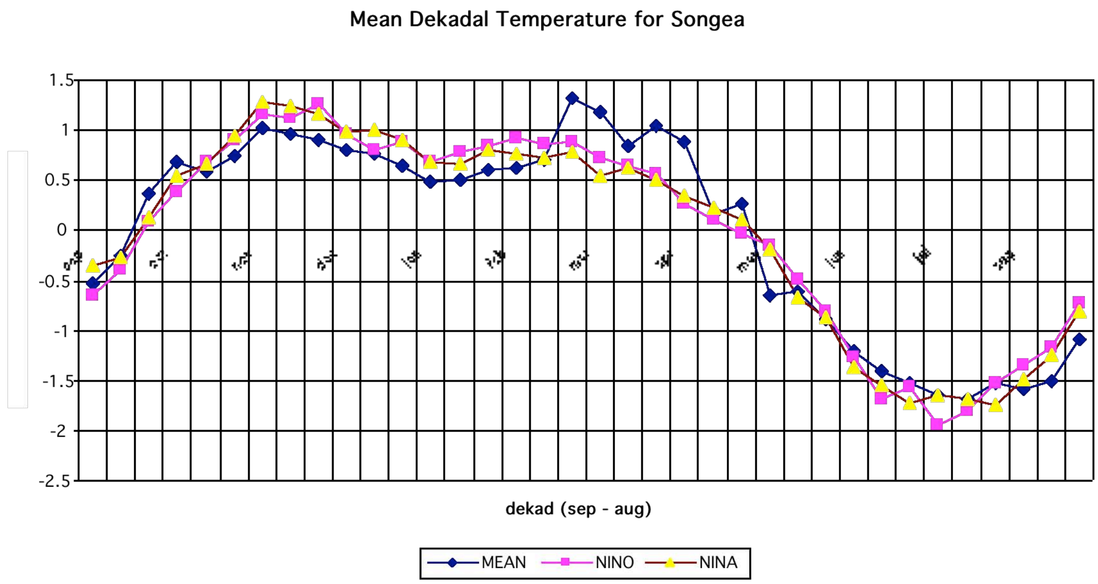

Figure 10: (b) average temperature from the only station

2.3.8 Zone 8 – South western highlands

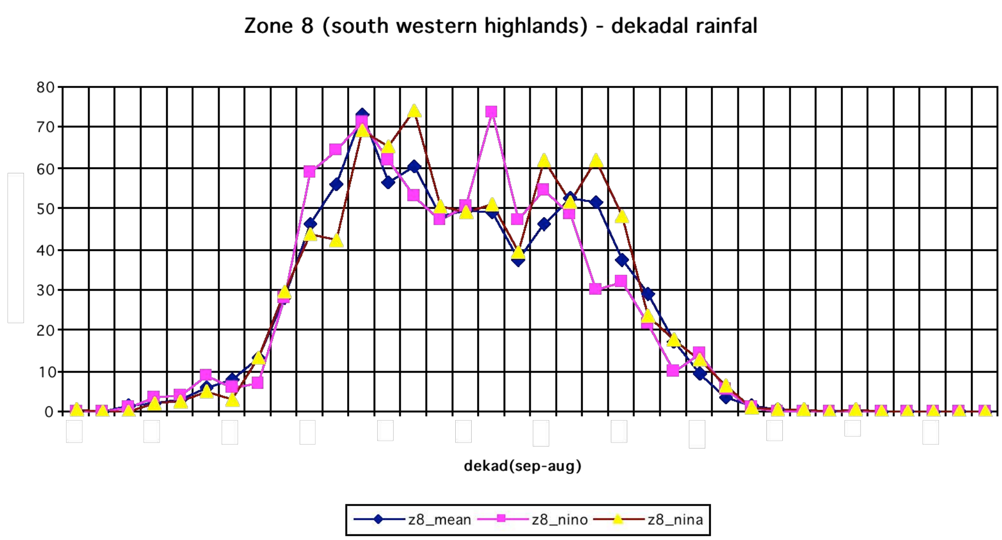

Figure 11: (a) areal average rainfall based on 7 stations

2.3.9 Zone 9 - (Western-Central areas)

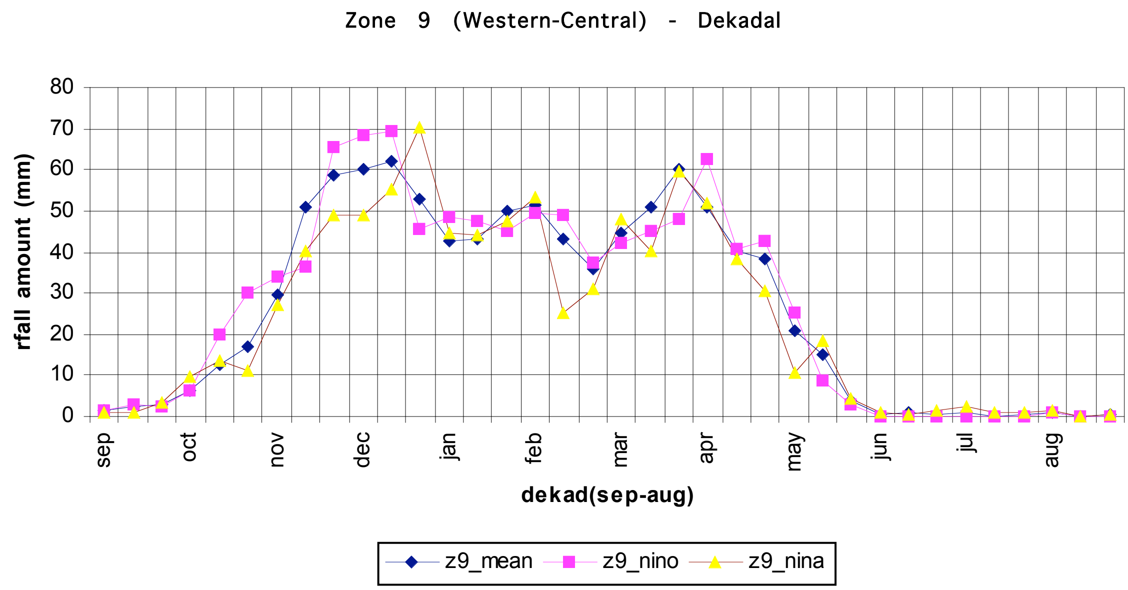

Figure 12: (a) areal average rainfall based on 7 stations

2.3.10 Zone 10 (western)

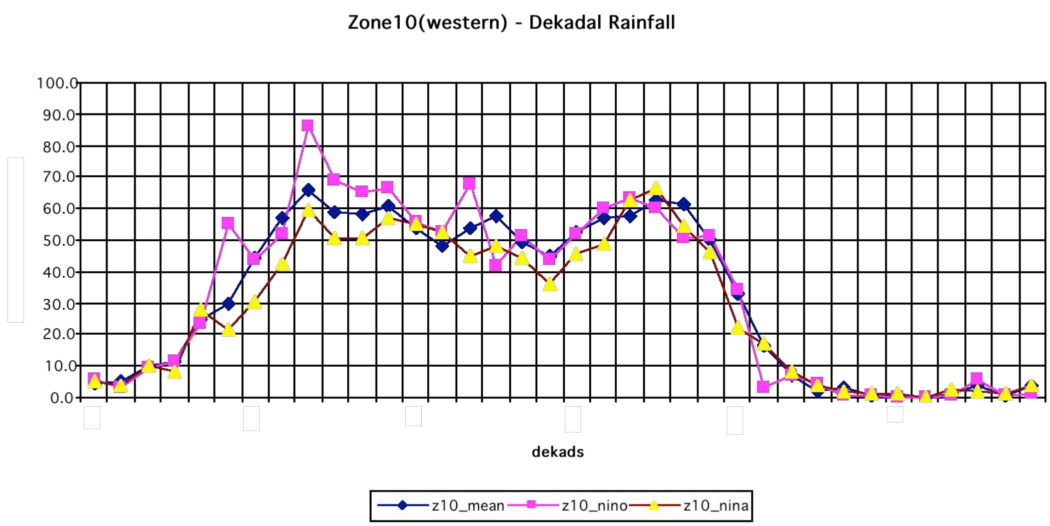

Figure 13: (a) areal average rainfall based on 5 stations

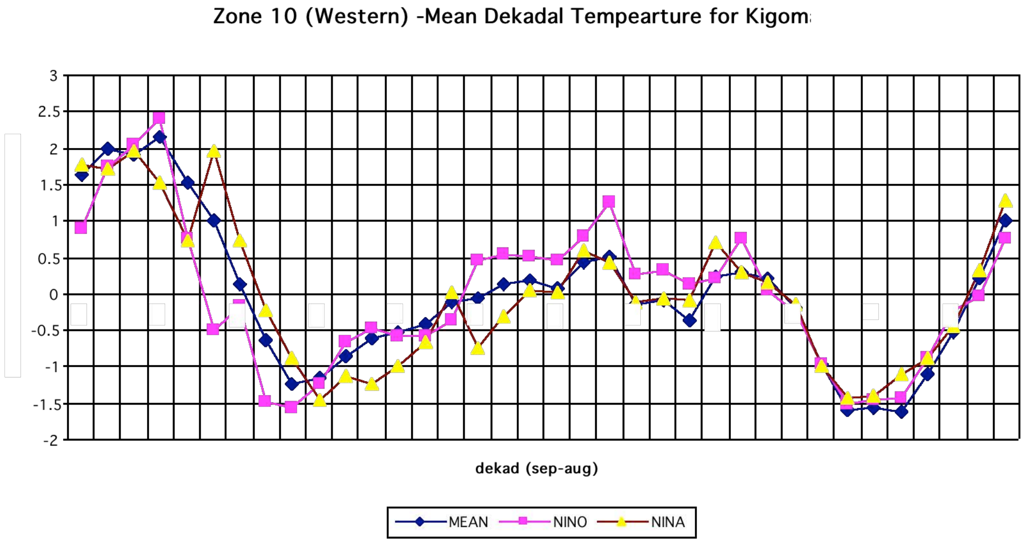

Figure 13: (b) areal average temperature based on the only station

2.4 Correlation between rainfall, temperature and SOI

Results obtained in 2.2 above indicate systematic/gradual temperature increase before onset of the seasonal rains. The rhythm for ENSO years was similar to that observed during normal years. This observation suggests energy import from somewhere, which plays a role in enabling rainfall development and onset of the seasonal rains.

It was interesting therefore to find out how SOI influences seasonal rainfall especially during ENSO years. Simple Pearson correlation matrices technique was employed to find out if there are some relationships between SOI, temperature and rainfall. The correlation matrices produce product-moment correlation coefficients. They vary between -1 and +1. A value of 0 indicates that neither of two variables can be predicted from the other by using a linear equation. A Pearson correlation of 1 or -1 indicates that one variable can be predicted perfectly by a linear function of the other. Correlation values ranging between –0.3 to –1.0 and 0.3 to 1.0 are considered significant in this study. Relationship between SOI and temperature from July to December was then established at homogeneous zone level. The analysis was similarly done using monthly rainfall in September when they set to December and seasonal totals (unimodal areas) averaged between November and February. The correlation values so obtained for the zones are presented in tables below.

2.3.1 Zone 1

	SOI
SOI	1.0
Z1_OCT_RAIN	- 0.4
Z1_NOV_RAIN	- 0.3
Z1_DEC_RAIN	-0.0
Z1_OND_RAIN	- 0.4
Z1_JUL_TEM	0.2
Z1_AUG_TEM	0.2
Z1_SEP_TEM	0.1
Z1_OCT_TEM	0.1
Z1_NOV_TEM	-0.0
Z1_DEC_TEM	0.0

2.3.2 Zone 2

	SOI
SOI	1.0
Z2_oct_rain	-0.4
Z2_nov_rain	-0.2
Z2_dec_rain	-0.0
Z2_ond_rain	-0.3
Z2_jul__tem	-0.0
Z2_aug_tem	-0.0
Z2_sep_tem	-0.1
Z2_oct_tem	-0.1
Z2_nov_tem	0.1
Z2_dec_tem	-0.0

2.3.3 Zone 3

SOI	1.0
Z3_oct_rain	-0.1
Z3_nov_rain	- 0.3
Z3_dec_rain	0.1
Z3_ond_rain	-0.1
Z3_jul_tem	- 0.5
Z3_aug_tem	- 0.4
Z3_sep_tem	- 0.6
Z3_oct_tem	-0.2
Z3_nov_tem	0.1
Z3_dec_tem	- 0.3

2.3.4 Zone 4

	SOI
SOI	1.0
Z4_OCT_RAIN	-0.4
Z4_NOV_RAIN	-0.2
Z4_DEC_RAIN	0.1
Z4_NDJF_RAIN	-0.1

2.3.5 Zone 5

	SOI
SOI	1.0
Z5_oct_rain	-0.2
Z5_nov_rain	-0.2
Z5_dec_rain	-0.0
Z5_ndjf_rain	- 0.3
dod_jul_tem	-0.2
dod_jul_tem	- 0.3
dod_sep_tem	-0.2
dod_oct_tem	- 0.5
dod_nov_tem	-0.1
dod_dec_tem	-0.0

2.3.6 Zone 6

	SOI
SOI	1.0
Z6_nov_rain	-0.2
Z6_dec_rain	-0.0
Z6_ndjf_rain	-0.1
Songea_ jul_tem	-0.2
Songea_aug_tem	- 0.3
Songea_sep_tem	- 0.4
Songea_oct_tem	- 0.4
Songea_nov_tem	- 0.3
Songea_dec_tem	- 0.3

2.3.7 zone 7

SOI	1.0
Z7_nov_rain	-0.2
Z7_dec_rain	-0.1
Z7_ndjf_rain	-0.2
mtwara_jul_tem	-0.2
mtwara_aug_tem	-0.2
mtwara_sep_tem	-0.1
mtwara_oct_tem	- 0.5
mtwara_nov_tem	- 0.3
mtwara_dec_tem	-0.1

2.3.8 Zone 8

	SOI
SOI	1.0
Z8_jul_tem	-0.2
Z8_aug_tem	- 0.3
Z8_sep_tem	- 0.4
Z8_oct_tem	- 0.5
Z8_nov_tem	-0.2
Z8_dec_tem	- 0.3
Z8_nov_rain	-0.2
Z8_dec_rain	-0.1
Z8_ndjf_rain	-0.1

2.3.9 Zone 9

	SOI
SOI	1.0
Z9_oct_rain	-0.1
Z9_nov_rain	0.0
Z9_dec_rain	0.0
Z9_ndjf_rain	-0.0
Tabora_jul_tem	- 0.6
Tabora_aug_tem	- 0.4
Tabora_sep_tem	- 0.6
Tabora_oct_tem	- 0.3
Tabora_nov_tem	0.0
Tabora_dec_tem	-0.2

2.3.10 Zone 10

	SOI
SOI	1.0
Z10_nov_rain	- 0.3
Z10_dec_rain	-0.1
Z10_ndjf_rain	- 0.3
Kigoma_jul_tem	- 0.3
Kigoma_aug_tem	-0.2
Kigoma_sep_tem	- 0.5
Kigoma_oct_tem	- 0.3
Kigoma_nov_tem	-0.1
Kigoma_dec_tem	- 0.6

3 RESULTS AND DISCUSSION

3.1 Seasonal rainfall variability over the bimodal areas

Figures 3 (a), (b) and (c) show standardized interseasonal rainfall anomalies during the period of study over the bimodal areas of Tanzania.
It is shown however that, although rainfall amounts during MAM are predominantly greater than OND, there are years when OND rains become much more and this is featured during El-Nino episodes. Similarly, OND have shown serious deficient rainfall in the years that featured La Nina events. It is also noted however that OND rainfall performs rather systematically during ENSO events unlike its erratic nature during other years outside this range.
This information may be useful for planning purposes especially for sectors, which are sensitive to rainfall intensity such as hydropower generation and water supply organizations.

3.2 Analysis of normal years versus composite El Nino and La Nina years

Analysis of Composite El-Nino and La Nina dekadal rainfall time series of all events occurring during the period 1961 – 2001 gave useful results as shown in figures 4 to 13.

3.2.1 Zone 1 - Northern Coastal Areas -

Onset

The mean (normal) year's rainfall pattern depicts onset dates to be between the 1^{st} and 2^{nd} dekad of October.

The El Nino (warm episode) year's rainfall patterns are characterized by an early onset with enhanced amount during the first dekad of October.
During El Nino the amounts are anomalously above normal for all dekads up to 2nd dekad of November when they normalize up to cessation.

The La-Nina (cold episode) year's rainfall patterns are characterized by an unreliable (erratic) onset (late dry spells during the following 2 dekads). Dekadal rainfall above 20 millimeters seem to stabilize in the 2nd dekad of November about 4 weeks later than during normal years

Cessation

General distribution of rainfall during La-Nina years depicts deficit rainfall condition throughout up to 2nd dekad of December when they normalize up to cessation in early January (end of December).

The general observation is that rainfall patterns for the cessation do not show significant differences (variation).

3.2.2 Zone 2 - North Eastern Highlands

Onset

The mean (normal) rainfall pattern depicts onset dates to be during 3rd dekad of October. Rainfall patterns during El-Nino (warm episode years depicts characteristics of early onset from the 1st dekad of October more than 2 weeks earlier than the normal year onset.

The rainfall patterns during La-Nino (cold episode) years indicate suppressed rainfall and a late onset in the 2nd dekad of November, marking almost 2 weeks delay relative to normal year onset dates.

Cessation

Cessation is around the end of December and does not show significant differences between different episodes and the mean.

The general distribution of rainfall throughout the October November December "OND" season is generally near normal with El Nino becoming above normal late November. However rainfall is suppressed thought the season during La-Nina years.

3.2.3 Zone 3 - Lake Victoria Basin -

Onset

The mean (normal) onset is during the second dekad of October.

The onset dates for both El Nino and La-Nina is at around the same period with little variation on the onset rainfall amounts.

Rainfall time series patterns during El-Nino (warm episodes)

The cessation during both El Nino and La-Nino years is during the first dekad of January but does not depict significant departure from the mean patterns.

The distribution throughout the season does not show significant differences between El Nino and mean patterns except in December when rainfall becomes enhanced during El-Nino years. Meanwhile rainfall is significantly below normal during October and November in La-Nino years.

3.2.4 Zone 4 - Northern Areas

Onset

The mean patterns indicate start of seasonal OND rainfall in the 1st week of November.

Onset during El-Nino years is earlier than the mean (normal) conditions with the onset in the 2nd dekad of October, some two weeks earlier than the normal onset dates.

During La-Nina years the onset is rather erratic with reliable onset starting as late as the 2nd dekad of December (failure). Rainfall only picks up to significant levels during the 2nd dekad of December and up to mid January. However rainfall continues by picking up in February where anomalous wet conditions are observed.

3.3 Results For the MAM (Long Rains) Rainfall Season

Onset

3.3.1 Northern Coast – Zone 1

Onset during a normal year is in the 2nd dekad of March. During El Nino and La-Nina years there is no significant shift of the onset and cessation dates. The overall rainfall distribution does not show significant differences too.

3.3.2 Northeastern Highlands- Zone 2

During MAM rainfall patterns for onset, seasonal distribution and cessation during El Nino and La-Nina years do not show significant differences with those of the normal years, except for enhanced rainfall during April in El-Nino years and earlier cessation by dekad during La-Nina years.

Cessation

General distribution of rainfall during La-Nina years depicts deficit rainfall condition throughout up 2nd dekad of December when they normalize up to cessation in early January (end of December).

The general observation is that rainfall patterns for the cessation do not show significant differences (variation).

3.4 Temperature variability

3.4.1 Like rainfall, analysis of the dekadal temperature for the three events during the period 1961 – 2002 also gave interesting results as noted in figures 7(b) to 10(b) and 13(b).

The annual temperature cycle in all the 10 zones reflects a systematic temperature increase before onset of the seasonal rains. The increase lasts for 5 to 7 dekads, counting from the first day of September before they get to an optimum. Temperature anomaly increases of up to 2° were common for most of the zones. The temperatures would then stabilize for several dekads between November and March for the unimodal areas and for two shorter periods coinciding with the two seasons peaking in November and April in the bimodal areas. Decaying of temperature in April and May coincided with end of seasonal rainfall in the unimodal regime and in June for the later regime. At this time the environment would loose temperature of up to 3° until July when the temperature is at its lowest.

The variation of temperature during onset, seasonal length and cessation may perhaps be attributed to heat transfer processes involving sensible heat, convection, latent heat, specific heat, etc all being energy sources measured by air temperature. Radiation balance and characteristics of air mass advection seems to be definitely controlling all the processes. The radiation balance and local air temperature could also be influenced by time of the day, day of the year, cloud cover and the nature of surface cover which might well explain the slight variations occurring among the 10 zones.

The onset of seasonal rains in all the zones occurs when the Inter Tropical Convergence Zone (ITCZ) is active and overlies the country. It creates an environment that is characteristic of deep convective activities characterized by abundant low level moisture, little shear in the horizontal and vertical, low level free convection, minimum convective inhibition, high equilibrium level, a forcing mechanism (e.g. sea breeze, outflow boundary) and other upper level saturation processes that would favor cloud development. The energy accrued out of these formative processes may perhaps involve energy dissipation that explains environmental temperature rise in the first few dekads of onset.

3.4.2 ENSO- Temperature teleconnection

The correlation between SOI, rainfall and temperature in the country was carried out as shown in the tables in 2.3 above. An inversely proportional relationship to temperature and rainfall was established. There was a gradual increased correlation between SOI and temperature from July to December with a peak in September in zones 6, 8, 9 and 10 in the unimodal areas and zone 3 in the bimodal areas. The correlation was very weak over the entire coastal strip and the north Eastern Highlands. This suggests a clear systematic forcing of the equatorial Pacific Ocean to the onset, sustainability and cessation of the seasonal rains in Tanzania especially during ENSO episodes.

4 CONCLUSIONS

From the experience that we have, negative SOI means there is an El-Niño under way leading to above average rainfall in the country. The more negative the index value, the higher is the likelihood for excessive rainfall. For example, the severe 1997-98 El-Niño was that its impact was such that about 80% of the country was severely affected by excessive rainfall, which left many regions under floods.

Conversely, positive values of SOI are associated with a La-Niña event, which in Tanzania is always accompanied by deficient rainfall. The more positive the indices, the likelihood for deficit rainfall. In 1973-74, the country experienced an intense La-Niña event. There was extensive famine throughout the country as a result.

As ENSO impacts are teleconnected to many regions of Tanzania, there is no doubt its knowledge provides valuable information for response toward mobilizing action to reduce vulnerability.

During warn El Nino events the onset of the October to December season is generally earlier by two to three weeks than normal in the northern sector of the country.

On the other hand during La Nina events the onset of the October to December rainfall is generally late by two to three weeks. During La Nina rainfall is also erratic and poorly distributed with long dry spells.

The cessation does not depict any significant shift from normal during both El Nino and La Nina.

OND (short rains) rainfall amounts during El Nino years are heavier than the MAM (long rains) amounts in the same year.

The systematic pick up of temperature at least two months before onset of seasonal rains in most areas in Tanzania may form an effective rainfall prediction tool during ENSO, in both the warm and cool events.
There is much room for improvement in view of existing global ENSO prediction models and those being developed, rapid evolving technologies and better observing systems sustained and generated by global programmes, including the Tropical Ocean Global Atmosphere (TOGA) etc.

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